Perceptual Load in Central and Peripheral Regions and Its Effects on Driving Performance With and Without Collision Avoidance Warning System

Hadas Marciano[1] and Yaffa Yeshurun[1]
(1) University of Haifa, Psychology Department, Haifa, Israel {hmarcia1@univ.haifa.ac.il; yeshurun@research.haifa.ac.il }

Abstract *– A driving simulator study was conducted to test the influence of Collision Avoidance Warning System on drivers' performance. Perceptual load on the road (e.g., vehicles' congestion) and its sides (e.g., pedestrians' number) were manipulated, while critical events occurred on the road (e.g., a leading car suddenly slowed down) or initiated from its sides (e.g., a pedestrian crossed the road unexpectedly). Each participant drove in four different scenarios: two with the warning system and two without. We found that at least in one condition (low levels of load in both regions) the system acted like a two-edged sword: On the one hand it decreased accidents with entities on the road, but on the other hand it increased accidents with entities arriving from the road sides. These findings demonstrate the importance of a systematic manipulation of perceptual load across the visual field and the critical events' location when evaluating drivers' behavior.*

Key words: *Perceptual load; In-Vehicle Warning System; Attention; Driving Simulator;*

Introduction

As we drive, information from different regions of the visual scene continuously reaches our eyes. Only some of it is relevant for safe driving. The ability to allocate attention only to the relevant information is a crucial factor in many car accidents. [Lav8] claimed that this ability is affected by the perceptual load in the scene. With high perceptual load, selectivity is high and attention is allocated only to the relevant information, but with low perceptual load selectivity is low and irrelevant information is also processed. Most of the studies which tested the perceptual load model manipulated load only in central regions of the visual field, leaving the load at more peripheral regions quite minimal (e.g., [Lav7]; [Lav9], see [Lav8] for a review). However, using simple letter stimuli, we [Mar13] orthogonally manipulated the levels of load in both relevant (central) and non-relevant (peripheral) regions. The results showed that increasing peripheral load deteriorated performance, but only with low levels of central load. Recent studies conducted in our lab have shown that when participants were asked to perform an additional second task at the periphery, and therefore had to allocate attention not only to the central region but also to more peripheral regions, additional resources could be recruited. This result has clear implication for driving behavior, as it suggests that drivers can (and do) allocate some attentional resources to the peripheral regions while driving, even under high levels of road load.

Several studies explored the influence of warning systems on drivers' behavior (for a review see [Gre6]). For instance, some of the studies that explored Collision Avoidance Warning Systems (like the one investigated in the current study) have shown an overall benefit for the employment of the system, especially concerning avoiding dangerous headways (e.g., [Ben2]; [Mal12]; [Shi15]). Other studies focused on comparing different modes of the systems. For example, [Abe1] compared three different kinds of timing of the alarm (early: 0.05 sec, middle: 0.64 sec, and late: 0.99 sec after the leading vehicle brakes) and found that a more appropriate response was related to the early alarm compared with either the middle or the late alarms. Another example is [Lee11] who compared different alert modalities (haptic vs. auditory) and different strategies (graded vs. single-stage). They found that graded haptic alerts might be preferable. Interestingly, a number of studies have shown that under some conditions the Collision

Avoidance Warning System may impair or may not benefit performance. For instance, [Bro4] claimed that overestimating the speed of human response can lead to a system which will not allow enough time for collision avoidance, and [Yam16] showed that an imperfect reliability of the system might lead to a reduction in drivers' performance instead of improvement.

However, none of the former studies explored in a systematic way the influence of warning system under different conditions of perceptual load, as was done in the current study. We employed two levels of perceptual load at two locations, the road itself and the sides of the road. The load levels on the road and on its sides were orthogonally manipulated to create four distinct combinations: high load on the road with low load on its sides, low load on the road with high load on its sides, low load in both regions, and high load in both regions. Critical events that required a rapid response (e.g., a pedestrian crossing the road) were also manipulated, half of them occurred on the road and half of them were initiated from its sides (see also [Mar15]). In addition, we compared driving without a Collision Avoidance Warning System to driving with such a system, in order to test whether the system improves driving performance, and if so whether this improvement is manifested in all load by event location combinations.

Method

Participants:

20 participants, 6 women and 14 men, average age 25.75 years (ranging from 22 to 31) took part in the experiment for monetary reward. All were students of the University of Haifa, and had driving experience of at least five years (with an average of 7.85 years).

Tools:

The experiment took place in a partial driving simulator using STISIM Drive™ software (Fig. 1). A Logitech steering system, which included steering wheel and two pedals – gas pedal and brake pedal – was used. The participant sat 2.5 m in front of a wide screen (2.3x3 m). This viewing distance was calculated to ensure that the perceived objects would have a similar visual angle to that in real life. Moreover, given the size of the screen and this viewing distance, critical events that were initiated from the sides of the road initiated from an eccentricity of 31º of visual angle (i.e., when the driver is fixating the middle of the road) which is also similar to real life. A speaker, providing background sounds, was placed behind the participant.

Fig. 1: The experiment setup.
The participant seats in a clerical chair, holding the wheel. The scenario is presented on a wide screen in front of the participant.

Scenarios:

Four different 23 km long scenarios were programmed. These scenarios simulated a suburban road with two lanes in each direction separated by a road median area. Each scenario consisted of four distinct different combinations of load on the road and on its sides: low load in both road and sides regions (LL, Fig. 2a), high load on the road with low load on its sides (HL, Fig. 2b), low load on the road with high load on its sides (LH, Fig. 2c), and high load in both road and sides regions (HH, Fig. 2d). The order of these four different load segments was balanced across the four different scenarios.

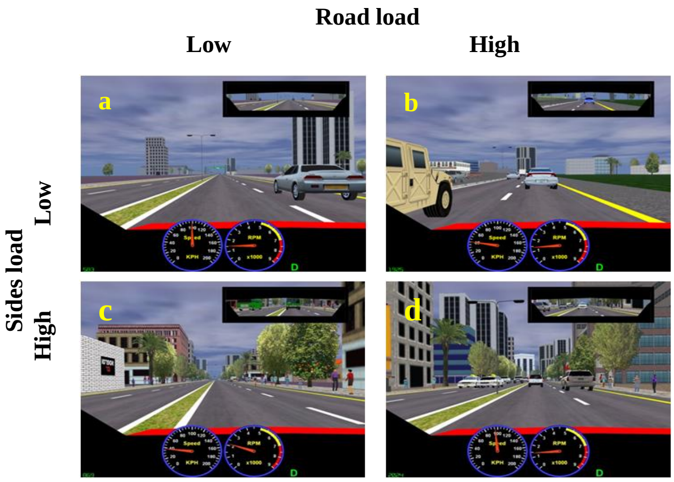

Fig. 2: Illustrations of the different load combinations in the experiment: a) LL: low load in both regions; b) HL: high load on the road, low load on its sides; c) LH: low load on the road, high load on its sides; d) HH: high load in both regions.

The load on the road was manipulated via the number and congestion of the vehicles. The load on the sides of the road was manipulated via the number of pedestrians, the density of the buildings, the presence of parked vehicles, etc. In each scenario 16 critical events were included, eight occurred on the road (e.g. a leading car suddenly slowed down), and eight were initiated from the sides of the road (e.g., a pedestrian crossed the road unexpectedly). Event location was balanced within the load conditions; in each load combination two events occurred on the road and the other two were initiated from its sides.

Collision Avoidance Warning System:

The warning system was programmed within the simulator. The criterion for its alarm activation was 2.5 seconds "time to collision" with a leading vehicle. This timing was chosen because pilot studies revealed that using it led to enough occurrences of the warning signal, but not too many, which might induce distrust in the system. The signal itself was an auditory signal of a brief pulsing tone.

Procedure:

Each participant came to the Lab for three meetings. In the first meeting the participant drove in a practice scenario of about 30 minutes, in order to get used to the simulator setting. The next two meetings included the experimental sessions and each lasted about one hour. In each experimental session the participant drove in two different scenarios. One of these scenarios included the activation of the Collision Avoidance Warning System, while the other scenario did not. The order of the scenarios' presentation and the order of the activation of the warning system within a session were balanced across participants.

In order to encourage the participants to drive at a speed that resembles real life driving, instead of slowing down to prevent accidents, they were informed that a monetary bonus would be given upon driving quickly. However they were also warned that each violation of the traffic regulations would result in a monetary penalty.

Results and discussion

Whole scenario analysis

For every load condition in each scenario of each participant the vehicle's median velocity and maximum velocity were calculated. These measures assessed the drivers' behavior in the whole scenario. Analysis of driving behavior that is constrained to the pre-planned events is presented later.

Vehicle's median velocity:

A three-way repeated measures Analysis of Variance (ANOVA) was conducted on the mean median velocity data. It included the variables of road load (low vs. high), sides of the road load (low vs. high), and the presence of a warning system ('with warning system' vs. 'without warning system'). The main effect of the road load variable was statistically significant [$F(1, 19) = 722.60$, $p < 0.0001$]; with low load on the road the median velocity was higher than with high load (70.1 kph vs. 48.3 kph, respectively). The main effect of the variable of sides load was also statistically significant [$F(1, 19) = 65.71$, $p < 0.0001$]; with low load on the sides of the road the median velocity was higher than with high load (61.3 kph vs. 57.1 kph, respectively). These findings demonstrate the effectiveness of the load manipulation, as increasing the levels of load resulted in slower driving.

The two-way interaction between the variables of road load and sides load reached statistical significance [$F(1, 19) = 30.51$, $p < 0.0001$]. As can be seen in Fig. 3 and confirmed by Least Square Difference (LSD) post hoc analyses, the increase in the perceptual load at the sides of the road led to reduction in the mean median velocity in both low and high road load conditions. However, the effect of sides load was modulated by the manipulation of road load, as this reduction was smaller and non-significant when the road load was high (low road load: 73.4 kph vs. 66.8 kph, $p < 0.0001$, for LL and LH conditions, respectively; high road load: 49.1 kph, vs. 47.4 kph, $p = 0.1406$, for HL and HH conditions, respectively). Because the road load involved central regions of the visual field and the sides load involved peripheral regions, this interaction is similar to the interaction between central and peripheral load found with simple letter stimuli in Experiments 1, 2a, and 2b in a former study we conducted [Mar13]. All these cases could be accounted for by the same explanation: With high levels of central load less attentional resources are available for the processing of peripheral information, resulting in a smaller effect of the load level at these peripheral regions. All other effects did not attain statistical significance ($F < 1$).

Note that the notion of the periphery here refers not only to the periphery of the visual field. This notion is also more conceptually driven, because when driving a car the road is often at the central focus of attention, while the sides of the road get less intentional resources. Therefore the sides of the road can be conceptualized as a more peripheral task.

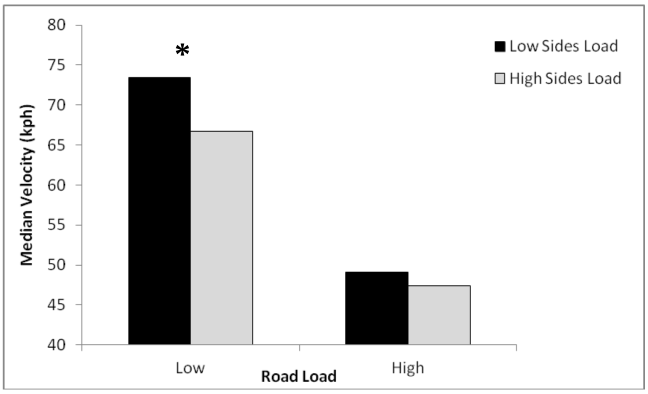

Fig. 3: Mean median driving velocity in the whole scenario as a function of road load and sides load.
The symbol '*' indicates a significant effect of the simple pairwise comparisons.

Vehicle's maximum velocity:

The same ANOVA was conducted on the mean maximum velocity data. The main effect of the road load variable was statistically significant [$F(1, 19) = 101.12$, $p < 0.0001$]; with low load on the road the maximum velocity was higher than with high load (91.5 kph vs. 84.5 kph, respectively). The main effect of the sides load variable was also statistically significant [$F(1, 19) = 119.86$, $p < 0.0001$]; with low load on the sides of the road the maximum velocity was higher than with high load (93.0 kph vs. 83.0 kph, respectively). As before, these significant effects of load indicate that the manipulation of load was successful. The main effect of the presence of the warning system was also statistically significant [$F(1, 19) = 5.55$, $p < 0.03$]; driving with the warning system reduced the maximum velocity compared to driving without such a system (88.7 kph vs. 87.4 kph, for the 'without warning system' and 'with warning system' conditions, respectively). Although the reduction in maximum velocity is quite small it implies that the Collision Avoidance Warning System may be an effective tool for reducing driving speed.

The two-way interaction between road load and sides load reached statistical significance [$F(1, 19) = 21.03$, $p < 0.0003$]. As can be seen in Fig. 4 and confirmed by LSD post hoc analyses, the interaction is similar to that found with median velocity. The perceptual load at the sides of the road significantly reduced the mean maximum velocity in both low and high road load conditions, but this reduction was smaller when the road load was high (low road load: 98.0 kph vs. 85.1 kph, for LL and LH conditions, respectively, $p < 0.0001$; high road load: 88.1 kph vs. 80.9 kph, for HL and HH conditions, respectively, $p < 0.0001$).

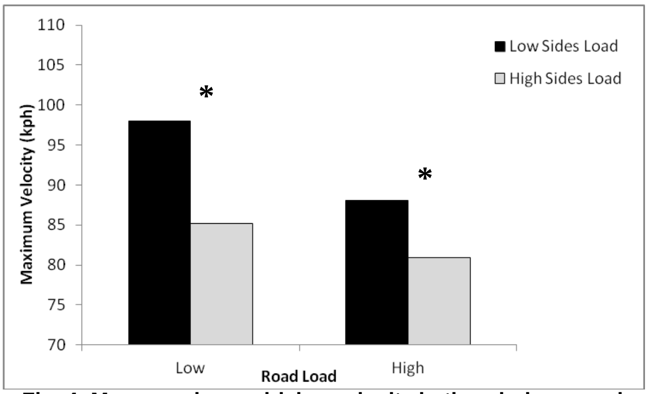

Fig. 4: Mean maximum driving velocity in the whole scenario as a function of road load and sides load. The symbol '*' indicates a significant effect of the simple pairwise comparisons.

The three-way interaction between road load, sides load, and the presence of the warning system also attained statistical significance [$F(1, 19) = 4.44$, $p < 0.05$]. LSD post hoc analyses showed that the effect of the warning system on maximum velocity was manifested in two different conditions of load combination (Fig. 5 and Table 1): LH ($p = 0.0734$) and HL ($p < 0.04$). In these two conditions the presence of the warning system decreased the maximum velocity compared with driving without such a system. When load was either low or high in both regions (LL and HH) no difference was found between driving with and without the warning system.

The lack of warning system effect in the LL and HH conditions may reflect ceiling and floor effects, respectively. When the load in both regions is low, one feels safe to drive as fast as possible regardless of the presence of the warning system. Yet, when the levels of load are high in both regions one may adopt more careful driving, and the result would be lower velocities with or without the warning system.

Table 1: Mean median velocity, maximum velocity, and number of accidents, in the whole scenario, in the various load x presence of warning system (WS) conditions.

		The presence of a WS	
Condition/Measure (kph)		Without WS	With WS
LL	Median velocity	73.5	73.4
	Maximum velocity	98.3	97.6
LH	Median velocity	67.1	66.4
	Maximum velocity	86.3	83.9
LH	Median velocity	49.1	49.2
	Maximum velocity	89.5	86.7
HH	Median velocity	47.7	47.0
	Maximum velocity	80.6	81.3

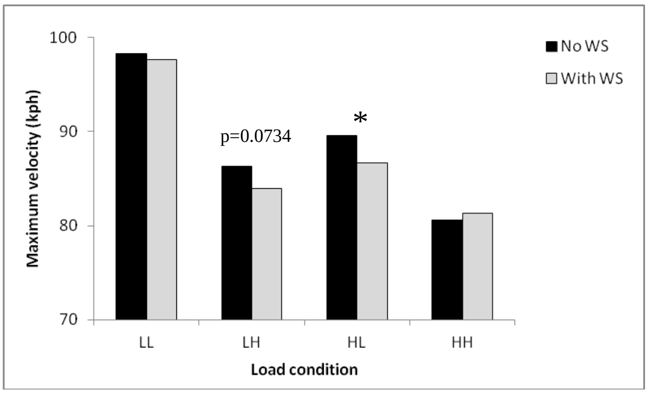

Fig. 5: Mean maximum velocity in the whole scenario as a function of road load, sides load, and the presence of Warning System (WS). The symbol '*' indicates a significant effect of the simple pairwise comparisons.

Although the presence of the warning system did not have dramatic effects on driving velocity, which was more affected by the load conditions on the road and on its sides, it did reduce significantly the maximum velocity that the drivers were ready to adopt. This reduction in maximum velocity implies that the presence of the warning system encouraged a more careful driving, probably because the participants tried to avoid its activation by maintaining a safer distance from a leading car. All other effects did not attain statistical significance (F<1).

Analysis of reactions to critical events: Proportion of accidents

The analysis presented in this section includes only accidents that occurred after a critical event (up to about 10 seconds after the event occurred). These are accidents that most likely were caused by the critical events. If an accident occurred for a specific event it was coded as 1 and if no accident occurred for that specific event it was coded as 0. These values were then averaged across all events of a specific condition. Hence, this measure represents the proportion of accidents that occurred per a specific condition.

A four-way repeated measures ANOVA was conducted on the mean proportion of accidents. It included the variables of road load (low vs. high), sides of the road load (low vs. high), event's location (road vs. sides of the road), and the presence of a warning system ('with warning system' vs. 'without warning system'). The main effect of the road load variable was statistically significant [$F(1, 19) = 8.62$, $p < 0.009$]; with low load on the road the proportion of accidents was higher than with high load (0.27 vs. 0.20, respectively). This effect might be due to the higher velocities adopted when the road load was low. The main effect of the event location variable was also statistically significant [$F(1, 19) = 23.00$, $p < 0.0001$]; when the event took place on the road the proportion of accidents was lower than when it was initiated from the sides of the road (0.16 vs. 0.30, respectively). This effect suggests that more attentional resources were allocated to the road than to its sides. The main effect of the warning system variable attained marginal significance [$F(1, 19) = 3.85$, $p = 0.0664$]; the proportion of accidents was lower when driving with the aid of the warning system compared to driving without such a system (0.21 vs. 0.26, respectively), suggesting that the warning system encouraged more careful driving.

The two-way interaction between the variables of road load and event location reached statistical significance [$F(1, 19) = 8.15$, $p < 0.02$]. LSD post hoc analyses revealed that the increase in the level of perceptual load on the road reduced the proportion of accidents, but only for events that were initiated from the sides of the road (road events: 0.17 vs. 0.16, sides events: 0.37 vs. 0.24, for low and high road load, respectively, $p < 0.0001$;Fig. 6). As mentioned above, when the levels of load on the road were high driving velocity was relatively low. This lower velocity helped the participants to avoid accidents when the events were initiated from the sides of the road – a less attended region of the visual field. When the events took place on the road itself, driving velocity probably did not play an important role. That is, when the load levels on the road were low and the event occurred on the road, it was relatively easy to spot the critical event and avoid an accident even with the high velocity adopted under low load conditions. Hence, there was no difference in the proportion of accidents for low and high road load for such events.

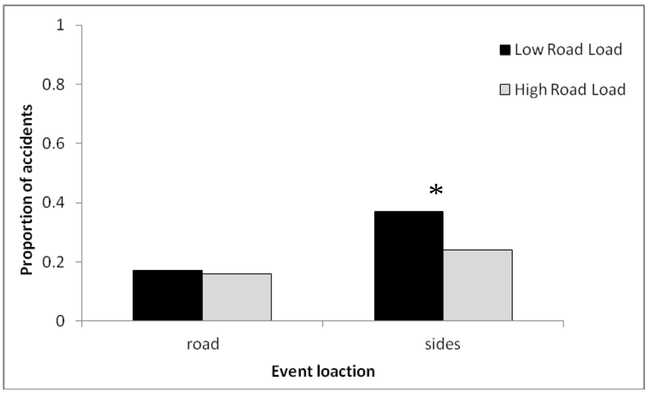

Fig. 6: Mean proportion of accidents following critical events as a function of road load and event location. The symbol '*' indicates a significant effect of the simple pairwise comparisons.

The two-way interaction between the variables of side load and event location was also statistically significant [$F(1, 19) = 5.24$, $p < 0.04$]. LSD post hoc analyses revealed that the increase in the level of perceptual load on the sides of the road significantly increased the proportion of accidents when the critical events initiated from the sides of the road (0.26 vs. 0.35 for low and high side load, respectively, $p < 0.002$; Fig. 7) but not when the events took place on the road itself (0.18 vs. 0.15 for low and high side load, respectively). This effect suggests that the higher levels of load on the sides of the road impaired the participants' ability to detect events initiating from the sides, resulting in a slower reaction to such unexpected yet relevant peripheral events. In fact, this finding suggests that some of these events were missed altogether and ended in accidents. In contrast, when the events occurred on the road, their detection was easy, regardless of load levels.

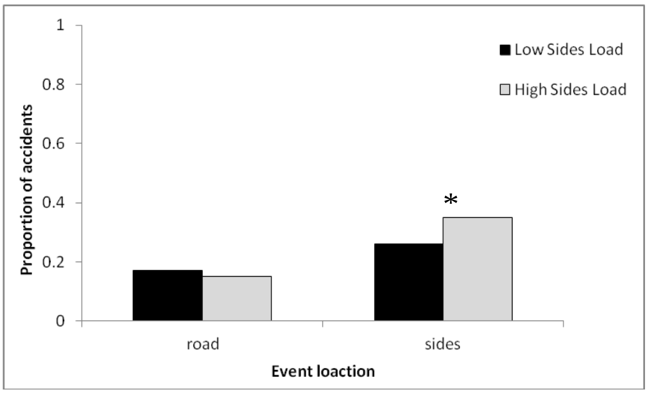

Fig. 7: Mean proportion of accidents following critical events as a function of sides load and event location. The symbol '*' indicates a significant effect of the simple pairwise comparisons.

The four-way interaction between the variables of road load, sides load, event location, and the presence of a warning system was marginally significant [$F(1, 19) = 3.55$, $p = 0.0748$]. As can be seen in Fig. 8 and in Table 2, and further confirmed by LSD post hoc analyses, when the event took place on the road the reduction in the proportion of accidents with the aid of the warning system was significant only in two load conditions: LL ($p < 0.005$) and HH ($p < 0.02$). It is possible that the warning system only helped in these two conditions because in the other two conditions – LH and HL – the proportion of accidents was already low even when driving without a warning system. More specifically, when there were more accidents while driving without the warning system, either because of high velocity (LL) or because of high levels of load at all regions (HH), the drivers could benefit from the presence of the warning system and a reduction in the proportion of accidents was found. Interestingly, for events that were initiated from the sides of the road there was a marginally significant opposite effect of the warning system: In the LL condition, the proportion of accidents was higher when driving with the warning system than without it ($p = 0.0768$). This finding suggests that with the warning system the drivers might allocate more attention to the road and therefore sometimes miss events that are initiated from the sides of the road. This seems to be particularly so when driving fast, as was the case in the LL condition. All other effects did not attain statistical significance.

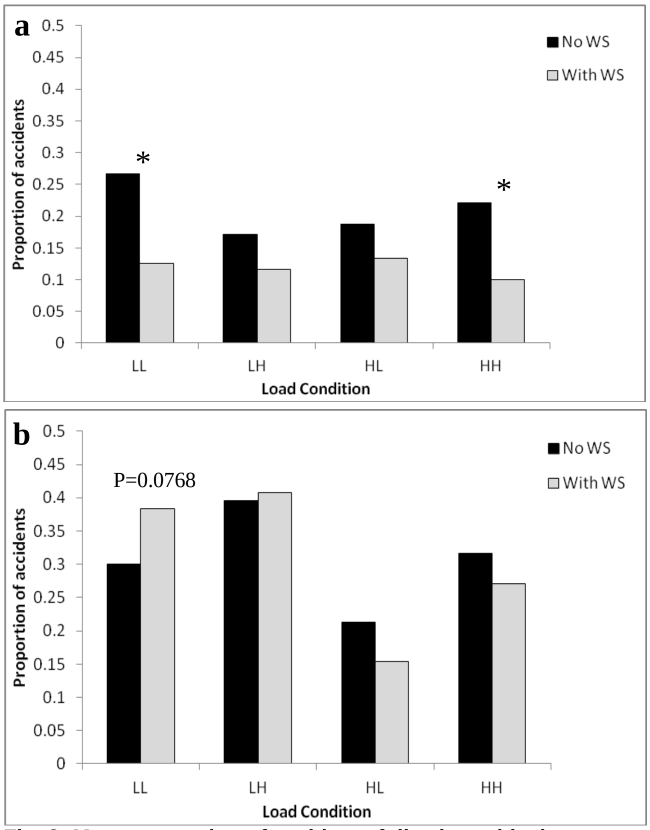

Fig. 8: Mean proportion of accidents following critical events as a function of road load, sides load, event location, and the presence of the warning system.
a) Events on the road; b) Events from the sides of the road. WS=Warning System.
The symbol '*' indicates a significant effect of the simple pairwise comparisons.

Table 2: Mean proportion of accidents in the various load x event location x presence of warning system (WS) conditions.

	Road events		Sides events	
Cond.	Without WS	With WS	Without WS	With WS
LL	0.27	0.12	0.30	0.38
LH	0.17	0.12	0.39	0.41
HL	0.19	0.13	0.21	0.15
HH	0.22	0.10	0.32	0.27

General Discussion

This study examined the effects of perceptual load on driving performance in a driving simulator. Additionally it tested the relevance of this setting – driving under varying levels of load in different regions of the visual field – for the evaluation of in-car warning systems, particularly a Collision Avoidance Warning System. Accordingly, the results will be discussed in relation to these two different issues.

Effects of perceptual load:

The degree of perceptual load and its location – on the road (central) vs. on road sides (peripheral) – played an important role in determining driving velocity. When the levels of load were low, particularly with load on the road, the participants adopted a higher driving velocity than when the levels of load were high. It is likely that the participants assumed that under low levels of load they can maintain adequate driving performance even when driving fast. It is important to note that the speedometer was clearly visible and that the average velocity in the LL condition was around 70 kph (which was the legal velocity limit for such roads). These two facts suggest that the participants were aware of their velocity, and therefore the higher velocity they adopted cannot be attributed to a simulator artifact. What is more, although in the LL condition the load on the sides of the road was low, there were nevertheless objects on the sides of the road (such as buildings, trees, parked cars, etc.). Therefore the peripheral cues, which might help the driver to estimate her own velocity in this condition, were not different from any other condition in the experiment.

The faster velocity driving strategy with low loads had considerable ramifications on the proportion of accidents, mainly with regard to events initiating from the sides of the road. For these peripheral events more accidents occurred when the level of the road load was low. Adopting high driving velocity when load levels were low was less detrimental for events that occurred on the road, probably because they were indeed easy to detect when the road load was low. Still, the danger involved in such a driving strategy is evident when considering just the data without the warning system (Fig. 8a). It is clear that the condition with the highest proportion of accidents is the one that may appear the easiest to drivers: low levels of load in both regions (LL).

The level of perceptual load at the sides of the road had a somewhat different effect on driving performance. Similar to the effect of road load, low levels of load on the sides of the road encouraged the participants to adopt a higher driving velocity, though this effect of sides load was modulated by the road load: The effect of sides load on velocity was larger when the road load was low than when it was high. Hence, the results in this natural setting experiment replicate our more controlled setting employed in a previous study [Mar13]. However, because with high levels of side load the detection of critical events, particularly those initiating from the sides of the road, was considerably harder, the overall effect of sides load on driving performance was different than that of road load. Specifically, unlike the road load conditions, higher proportion of accidents was found for sides events when the level of side load was high than when it was low.

Evaluation of the Collision Avoidance Warning System:

The effects of the warning system found in this experiment were rather small, but they nevertheless suggest that this kind of Collision Avoidance Warning System probably has some merit. On some of the load conditions, the presence of the warning system lowered the maximum velocity of the vehicle and decreased the proportion of accidents that involved events occurring on the road. Similar effects of warning system on mean velocities were reported by [Bir3]. However, the effects of the warning system in the current study were not always beneficial. When the levels of perceptual load were low in both regions of the visual field, driving with the warning system resulted in a higher proportion of accidents that involved sides' events than driving without the system. This finding may reflect an effect of the warning system on the pattern of attentional allocation. Specifically, the warning system may lead to withdrawal of attentional resources from the sides of the road for the purpose of reallocating them to the road itself. This strategy is likely adopted to avoid the activation of the system's alarm, but it also results in decreased ability to detect events that initiate from the sides of the road. Although this detrimental effect of the warning system was only marginally significant it underscore the importance of evaluating such warning systems under varying levels of load at different regions of the visual field and with different types of critical events, as was done in the current study.

Because the effects of the warning system were relatively small, further research, with finer tuning of the implementation of the system in the simulator, is required to reach any strong conclusions. However, the pattern of results found in this study implies that the presence of the Collision Avoidance Warning System might act like two-edged sword**:** On the one hand it enhanced driving safety by preventing accidents with a leading car on the road. But on the other hand, in some conditions, it increased the probability of accidents when the critical events initiated from peripheral regions, compromising the safety of different entities located on the sides of the road.

Finally, we would like to discuss the possible limitations of the simulator. We are aware, of course, that driving in real life is not the same as driving in simulators. However, we believe that many variables that govern performance in the simulator also affect driving in real life, especially when the focus is on higher cognitive processes (such as attention which was the main process we considered). [Lee10] and [Dew5] are two examples that demonstrate the validity of driving simulators to real road performance. Both studies found high correlations between their participants' performance in the simulator and their performance in real driving tasks.

To sum, this study demonstrates the importance of the experimental paradigm employed here for the research of driving behaviour. The paradigm controls the load on the road and on its sides and also controls the location of critical events. Without these manipulations the current study would have suggested that the warning system is always beneficial. However, the load by event location manipulation revealed that this is not always the case.

References

[Abe1] Abe, G., & Richardson, J." The effect of alarm timing on driver behaviour: an investigation of differences in driver trust and response to alarms according to alarm timing". *Transportation Research*, 2004, F7(4-5), 307–322.

[Ben2] Ben-Yaacov, A., Maltz, M., & Shinar, D. "Effects of an invehicle collision avoidance warning system on short and longterm driving performance". *Human Factors*, 2002, 44, 335–342

[Bir3] Birrell, S.A., & Young, M. S., "The impact of smart driving aids on driving performance and driver distraction". *Transportation Research*, 2011, F(14), 484–493.

[Bro4] Brown, T. L., Lee, J. D., & McGehee, D. V. "Human performance models and rear-end collision avoidance algorithms". *Human Factors*, 2001, 43, 462–482.

[Dew5] de Winter J. C.F., de Groot, S., Mulder, M., Wieringa, P. A., Dankelman, J., & Mulder, J. A. "Relationships between driving simulator performance and driving test results". *Ergonomics,* 2009, 52(2), 137-153

[Gre6] Green, P., Sullivan, J., Tsimhoni, O., Oberholtzer, J., Buonarosa, M.L., Devonshire, J., Schweitzer, J., Baragar, E., & Sayer, J. "Integrated vehicle-based safety systems (IVBSS): Human factors and driver-vehicle interface (DVI) - Summary report". *Report to National Highway Traffic Safety Administration*, 2008.

[Lav7] Lavie, N. "Attention, distraction, and cognitive control under load". *Current Directions in Psychological Science*, 2010, 19(3), 143-148.

[Lav8] Lavie, N. "Perceptual load as a necessary condition for selective attention". *Journal of Experimental Psychology: Human Perception and Performance*, 1995, 21, 451-468.

[Lav9] Lavie, N., & Cox, S. "On the efficiency of attentional selection: Efficient visual search results in inefficient rejection of distraction". *Psychological Science*, 1997, 8, 395-398.

[Lee10] Lee, H. C. "The validity of driving simulator to measure on-road driving performance of older drivers". *Transport Engineering in Australia*. 2003, 8(2), 89-100.

[Lee11] Lee, J. D., Hoffman, J. D., & Hayes, E. "Collision warning design to mitigate driver distraction". *Proceedings of the SIGCHI conference on Human factors in Computing Systems*, 2004, 65-72, Vienna, Austria.

[Mal12] Maltz, M., & Shinar, D. "Imperfect in-vehicle collision avoidance warning systems can aid drivers". *Human Factors*, 2004, 46(2), 357–366.

[Mar13] Marciano , H. &Yeshurun, Y. "The effects of perceptual load in central and peripheral regions of the visual field". *Visual Cognition*, 2011, 19(3), 367-391.

[Mar14] Marciano , H. &Yeshurun, Y. "Perceptual load in central and peripheral regions and its effects on driving performance: Advertizing billboards", *Work: A Journal of Prevention, Assessment and Rehabilitation*, 2012, 41, 3181-3188.

[Shi15] Shinar, D., & Schechtman, E. "Headway feedback improves inter-vehicular distance: A field study". *Human Factors*, 2002, 44, 474–481

[Yam16] Yamada, K. & Kuchar, J. K. "Preliminary study of behavioral and safety effects of driver dependence on a warning system in a driving simulator". *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans,* 2006, 36(3), 602-610. http://ntl.bts.gov/lib/30000/30200/30257/14433_files/14433.pdf

Acknowledgments

This study was supported by THE RESEARCH FUND ON INSURANCE MATTERS to Y. Yeshurun, and by THE ISRAEL NATIONAL ROAD SAFETY AUTHORITY doctoral fellowship to H. Marciano